

The Economics of Reduced Tillage and Reduced Summer Fallow in Crop Production in Canada: A Review of Available Evidence¹

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THE ECONOMICS OF REDUCED TILLAGE AND REDUCED SUMMER FALLOW IN CROP PRODUCTION IN CANADA: A REVIEW OF AVAILABLE EVIDENCE

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Abstract

This paper reviews recent trends in the use of summer fallow and reduced tillage production systems in grain and oilseed production in eastern and western Canada. The emphasis in his review is placed on the most recent national data. Expert opinion and published literature is used to evaluate and interpret these trends. Energy use comparisons for different crop production systems are reported. Areas for further research are identified.

1. INTRODUCTION

The purpose of this paper is to review recent trends in the use of summer fallow and reduced tillage in crop production in Canada with a view toward identifying the factors contributing to changes in the use of these production systems in recent years. Where possible, the implications of changes in the use of summer fallow and reduced tillage for per hectare energy consumption are explored. This paper is intended only to review available data and research findings and to highlight areas for further research.

The last decade has witnessed substantial changes in the use of reduced tillage systems by grain and oilseed producers in Canada. Historically, producers have mechanical tillage to control weeds and for seedbed preparation. This approach generally provided producers with higher and more stable short term incomes (Zentner et al. 1998b; Zentner and Campbell 1998). More recently, improvements in technology and in management practices have made it more attractive for producers to reduce their reliance on mechanical tillage operations and to subsequently reduce their production costs. In addition, growing concern about the long term effects of traditional tillage practices on soil quality and about the off-farm effects of displaced sediment from tillage operations have been important regional issues.

2. REDUCED TILLAGE AND SUMMERFALLOW IN WESTERN CANADA

Tables 1 and 2 summarize the aggregate trends in the adoption of reduced tillage practices in western Canada for the 1991 and 1996 Census of Agriculture. The use of conventional tillage declined across all of the western provinces between 1991 and 1996. The growth in the adoption of conservation tillage reflects the trend towards the use of more extended and diversified rotations over more traditional rotations consisting mainly of monoculture cereals and fallow. Extended and diversified rotations are complementary to the use of zero tillage. In 1996, Saskatchewan had the highest adoption rate for zero tillage while accounting for 53.39 percent of the total land in crops for western Canada. Overall trends in the adoption of conservation tillage in the rest of western Canada closely mirror those of Saskatchewan. As a result, the total land in crops for western Canada managed under conventional tillage declined from 67.22 percent in 1991 to 51.74 percent in 1996. During this period zero tillage adoption increased from 7.16 percent to 16.28 percent.

3. ACCOUNTING FOR RECENT TRENDS IN WESTERN CANADA

In western Canada, reduced tillage production systems produce the best returns when combined with extended and diversified crop rotations where high herbicide requirements on fallow land can be avoided. This is reflected in the growth in adoption rates of conservation tillage levels and reductions in fallow across the prairies. Results from the 1996 Census of Agriculture show that for the province of Manitoba between 1991 and 1996 the hectares of land managed under conventional tillage declined 10.4 percent, fallow hectares grew by nine percent, while zero till hectares grew by 70.4 percent. For the province of Saskatchewan hectares managed under conventional tillage declined 27.0 percent, fallow hectares declined 22.4 percent, and zero till hectares increased 116.9 percent.

Table 1 Proportion of cropland area under alternative tillage practices in Western Canada, 1991 and 1996

	Manitoba		Saskatchewan		Alberta		British Columbia		Western Canada	
	1991	1996	1991	1996	1991	1996	1991	1996	1991	1996
Conventional Tillage	66.30	63.34	63.93	45.28	72.59	56.80	83.45	65.48	67.22	51.74
Minimum Tillage	28.66	27.51	25.68	32.87	24.28	32.87	11.92	24.43	25.61	31.97
No Tillage	5.02	9.13	10.37	21.83	3.11	10.32	4.62	10.08	7.16	16.28

Source: Statistics Canada, Census of Agriculture.

Table 2 Cropland Area Under Alternative Tillage Practices in Western Canada, 1991 and 1996

	Manitoba		Saskatchewan		Alberta		British Columbia		Western Canada	
	1991	1996	1991	1996	1991	1996	1991	1996	1991	1996
Conventional Tillage	2797467	2507655	8333697	6085007	5783499	4313072	201084	117280	17115747	13023014
Minimum Tillage	1209493	1089365	3348473	4417319	1934381	2495667	28742	43753	6521089	8046104
No Tillage	212093	361482	1352823	2934194	248521	783622	11137	18052	1824574	4097350

Source: Statistics Canada, Census of Agriculture.

For Alberta the hectares of land managed under conventional tillage declined 25.4 percent, fallow hectares declined 18.9 percent, and zero till hectares increased 215.3 percent (Statistics Canada, 1997). A 1997 Statistics Canada survey shows that the trends in adoption rates are greatest in the black and gray soil zones, intermediate in the dark brown soil zone, and lowest in the brown soil zone (Statistics Canada, 1997). These results are as expected given the results of the research on the economic performance of zero tillage.

Increases in adoption rates for reduced tillage practices during the last decade can be attributed to several factors. Increased availability of equipment required for seed and fertilizer placement in heavy crop residue, improvements in residue management, greater availability of non-selective herbicides and reductions in the recommended application rates have reduced production costs and improved weed and disease control have all contributed to improved economic performance of reduced tillage. Conventional tillage in western Canada typically involves 5 field operations. Zero tillage makes it possible to eliminate four of these operations (Burton and Green 1995), reducing fuel, labour and machinery costs. However, herbicide costs are generally greater under reduced tillage since these chemicals are substituted for mechanical tillage. The potential cost savings from substituting mechanical tillage for herbicides is greatest when zero tillage is employed on wetter soil soils where more tillage operations as generally required and declines when compared to dryer soils (gray to black to dark brown to brown) (Zentner et al. 1998a). On soils with higher moisture levels it also becomes possible to eliminate the use of fallow since zero tillage is able to restore the soils moisture levels to that which can be achieved under the use of fallow.

The profitability of zero tillage systems is greatly influenced by the soil type, crop types and rotations employed (See Table 3). On dry soils such as brown, conventional tillage is the most profitable under wheat-fallow rotations. In wetter soils where more diverse rotations are more common zero tillage practices are generally more profitable as there are some yield advantages under zero tillage. Zentner et al. (1996) report that conventional tillage produced higher net returns when compared with zero tillage for fallow-wheat rotations in the brown soil zone. This was due to a lack of any yield advantage under zero tillage and production costs that averaged 22 percent higher. In the more moist black soil zone, Lafond et al. (1993) report zero tillage produces higher profits when compared to conventional tillage for diversified rotations. This was due to a 10 to 21 percent yield

advantage for crops grown under zero till and a lack of any significant difference in production costs among the two systems. Brandt (1992) reports similar finding in the dark brown soil zone where diversified rotations which include wheat and oilseeds produced a 6 percent yield advantage under zero tillage when compared to conventional tillage. Blomert et al. (1997) also report that on the gray soil net returns were higher under zero tillage when compared to conventional tillage for mixed cereal-oilseed rotations. The greatest economic potential for zero tillage lies with extended and diversified crop rotations and the elimination of summerfallow.

Table 3 Summary of economic studies comparing zero tillage (zt) and conventional tillage (ct)

Soil Zone	Yield	Machinery and Fuel Costs	Herbicide Costs	Net Returns
Brown	zt=ct	zt<ct	zt>ct	ct>zt
Dark brown	zt>ct	zt<ct	zt>ct	ct>zt zt>ct
Thin black	zt>ct	zt<ct	zt>ct	zt>ct
Black	zt=ct	zt<ct	zt>ct	zt>ct
Gray	zt=ct	zt<ct	zt>ct	zt>ct

Studies comparing the economic performance of conventional and reduced tillage in western Canada date back to the late 1970s and early 1980s. The results of these early studies showed that cropping systems which employed conventional tillage were consistently more profitable than those which employed zero tillage (Zentner and Lindwall 1978, 1982; Zentner et al. 1988a). Conservation tillage practices performed poorly in these early studies due to high expenditures on herbicides due to high unit costs and very limited availability of non-selective herbicides, lack of significant yield advantage due to inadequate weed control and moisture conservation, and poor equipment design and performance for seed and fertilizer placement in heavy crop residues. These early studies also focused heavily on cropping systems that included monoculture cereals and high levels of summerfallow

(Zentner et al. 1998b). However, technological improvements during the last 10 years have removed many of the factors which limited the economic performance of conservation tillage in earlier studies. Improved machinery, improvements in residue management, greater availability of non-selective herbicides, reductions in recommended rates of herbicide application and the increases use of extended and more diversified crop rotations have improved the economic performance of conservation tillage management and increasing adoption rates among producers.

Reduced tillage also offers soil conservation benefits compared to that which can be obtaining under conventional tillage. Reduced tillage management systems make use of anchored stubble to reduce water and wind soil erosion, conserve soil moisture levels, and maintain soil nutrient quality (Lafond et al. 1996). Van kooten et al. (1989) estimate that the annualized user cost of soil erosion can range between \$2.38 to \$5.63/ ha⁻¹. Lafond et al. (1993) estimate the potential replacement value of organic soil matter lost to erosion (nitrogen, phosphorous and potassium) in a continuous rotation of wheat to be \$13000/ ha⁻¹. By using zero tillage to maintain or improve soil quality it is possible to have higher levels of soil carbon sequestration and lower levels of carbon dioxide released into the atmosphere when extended crop rotations are employed.

4. REDUCED TILLAGE USE IN EASTERN CANADA

Tables 4 and 5 summarize the aggregate trends in the use of reduced tillage in eastern Canada observed in the 1991 and 1996 census of agriculture. The use of conventional tillage in Ontario fell from 78.19 percent to 59.48 percent during the five intercensus years. Most of the change occurred as a result of increase use of no-till. Most of the increase in conservation tillage in Ontario occurred in soybeans. Increases in the use of reduced tillage in corn production were modest during this five year period and followed a steady but gradual trend toward increased use of reduced tillage in corn that began in the early 1980's.

One of the more popular rotations in Ontario has become corn followed by two years of soybeans followed by wheat, so the increased use of reduced tillage in soybeans has double the impact on aggregate use of reduced tillage that an increase in corn or wheat would have. Since 1996 indications are that the rate of adoption of reduced tillage in crop

production in Ontario has slowed down and may have even levelled off. Given that Ontario accounted for approximately 70 percent of total land area prepared for seeding in eastern Canada in 1996, the overall trends in the use of reduced tillage in eastern Canada closely follow the trends for Ontario. Consequently, 80.48 percent of the total land area prepared for seeding in eastern Canada was prepared with conventional tillage in 1991. This fell to 65.54 percent in 1996.

5. ACCOUNTING FOR RECENT TRENDS IN EASTERN CANADA

Increased use of reduced tillage in soybeans during the 1990's in eastern Canada occurred as a result of several factors. Seed drills suitable for planting soybeans in a reduced tillage management system became more widely available commercially in the early 1990's. Existing and new varieties were found to yield well under reduced tillage and disease resistance with new varieties has been an asset in reduced tillage production. Reduced tillage requires fewer field operations per production cycle. Typically (Zantinge et al.) conventional tillage in Ontario can involve up to 5 tillage operations per crop cycle. Reduced tillage can involve only two and no-till, obviously, none at all. One advantage of reduced tillage is that the producer spends less time transporting tillage equipment, often by road, from one field to another. This allows producers to realize economies of size in crop production. It has also increased competition for rented land in many areas because it is profitable for producers to travel farther to work rented land when fewer field operations are necessary. The available data on profitability of reduced tillage systems are not recent. Zantinge et al. (1986) compiled detailed budget data on alternative tillage systems for corn production in southern Ontario. Their findings indicated that no-till corn had lower overall input costs than conventional tillage or reduced tillage but that yield reductions of up to 11 percent under no-till made that system 14-16 percent less profitable than conventional tillage. Improved management practices in no-till corn have reduced typical yield losses since the Zantinge study was published, even eliminating them for some soil types, but the risk of yield penalties remains an important disincentive for many producers.

Table 4 Proportion of cropland area under alternative tillage practices in Eastern Canada, 1991 and 1996

	Ontario		Quebec		New Brunswick		Prince Edward Island		Nova Scotia		Newfoundland		Eastern Canada	
	1991	1996	1991	1996	1991	1996	1991	1996	1991	1996	1991	1996	1991	1996
Conventional Tillage	78.18	59.48	85.16	80.12	85.25	79.50	91.23	81.96	88.34	77.43	84.11	87.67	80.48	65.54
Conservation Tillage	17.78	22.29	12.30	15.63	12.50	18.39	7.86	16.25	7.83	19.58	7.66	8.31	15.98	20.44
No Tillage	4.03	18.23	2.54	4.25	2.25	2.11	0.91	1.79	3.83	2.99	8.23	4.02	3.55	14.02

Source: Statistics Canada, Census of Agriculture.

**Table 5 Cropland area under alternative tillage practices in Eastern Canada
1991 and 1996**

	Ontario		Quebec		New Brunswick		Prince Edward Island		Nova Scotia		Newfoundland		Eastern Canada	
	1991	1996	1991	1996	1991	1996	1991	1996	1991	1996	1991	1996	1991	1996
Conventional Tillage	4846165	3667924	1792763	1643948	129942	114812	251851	236609	69120	45725	4260	2310	7094101	5711328
Conservation Tillage	1102043	1374771	258998	320777	19049	26555	21698	46914	6123	11562	388	219	1408299	1780798
No Tillage	250045	1124456	53383	87222	3426	3048	2517	5161	3000	1767	417	106	312788	1221760

Source: Statistics Canada, Census of Agriculture.

6. EFFECTS ON ENERGY USE

Agricultural production in western Canada relies heavily on the input of nonrenewable energy. Hopper (1984) estimated that it took 4.5 MJ of nonrenewable energy inputs to produce one kg of wheat in 1981. Zentner et al. (1998a) report that they required 4.4 MJ of nonrenewable energy inputs to produce one kg of wheat. Total requirements for nonrenewable energy inputs remains high and much of this energy consumption results from the heavy use of fuels in farm mechanization as well fertilizers and herbicides. Conventional tillage has a higher fuel energy requirement on a per hectare basis when compared with zero tillage practices. Henry (1994) reports that for a diversified wheat-pea-wheat-canola rotation in the black soil zone energy expended in the form of fuel on a per hectare basis for the four year rotation was 8205 MJ under zero tillage and 12306 MJ under conventional tillage. By reducing the use of mechanical tillage the fuel energy savings are clear. The proportion of energy on a per hectare basis expended on herbicides under zero tillage was 2348 MJ compared to 1434 MJ under conventional. Zentner et al. (1998a) report that for a fallow-wheat system on the brown soil zone, fuel energy expended under zero tillage averaged 986 MJ/ha⁻¹ under conventional tillage and 667 MJ/ha⁻¹. The proportion of energy expended on herbicides averaged 287 MJ/ha⁻¹ under conventional tillage and 634 MJ/ha⁻¹ under zero tillage. Zero tillage systems do reduce the use of energy in the form of fuel but part of this savings can be offset the in increase in energy use in the form of herbicide. Zentner et al. (1993) also show that for a fallow-wheat rotation in the brown soil zone fuel consumption decreases from 33 L/ha under conventional tillage to 26L/ha under zero tillage. These fuel savings can greatly reduce emissions of CO₂ produced during crop production since it is estimated range from 25 to 30 kg CO₂ -C/ha (Jacques 1992). It is important to note that nonrenewable energy in the form of fertilizer can account for up to 50 percent of the total energy input required in a crop production system (Zentner et al. 1998). Reducing energy inputs in the form of fertilizer has the potential to create a large energy savings. More research is needed to determine the suitability of present nitrogen fertilizer recommendations for use in zero tillage production systems since they were originally developed for use in conventional tillage systems.

Zantinge et al. compared input use for conventional tillage, reduced tillage, mulch tillage and no-till for continuous corn production in southern Ontario. Because conventional tillage uses more field operations per hectare per crop cycle, more fuel is required. According to their data, conventional tillage consumes 58.2 litres of fuel per hectare per year. No-till used only 28.4 litres per hectare per year. But the no-till system required three times more herbicide and this is an energy intensive input. Swanton and Clements have documented the improvements in energy productivity in Ontario crop production between 1975 and 1991. According to their data conventional tillage corn production used 508 litres of diesel-fuel equivalent per metric ton of corn produced in 1975. This had fallen to 319 litres by 1991. Most of the gain came about through more efficient use of fertilizer and reduced energy embodied in plant protection products. Energy use in soybeans followed a similar pattern, with energy inputs of 174 litres of diesel fuel equivalent per metric ton of grain produced in 1975 but only 95 being used in 1991. Overall, Swanton and Clements estimate that improvements in energy productivity reduced overall energy use in corn production in Ontario by 24 percent between 1975 and 1991 even though production increased by 60 percent during that time period. During the same time period, soybean production in Ontario increased by 278 percent but energy use increased by only 82 percent. If 1975 energy technology and management were used to produce 1991 output, an additional 276 million litres of diesel fuel equivalent would have been needed over and above the estimated 191 million litres actually used in corn and soybean production in 1991.

7. IMPACTS OF TILLAGE MANAGEMENT ON CARBON SEQUESTRATION

Zero tillage management practices have the ability to reduce wind and water soil erosion and preserve soil quality. This is accomplished by making use of anchored stubble and lowering the level of soil disturbance by reducing mechanical tillage. Soils have been identified as playing an important role in soil carbon storage as well. The use of fallow and heavy mechanical tillage reduces the ability of soil to store carbon because inputs of carbon are relatively low and soil organic matter is accelerated by frequent tillage operations (Curtin et al. 1994). Zero tillage has the potential to stabilize or re-build the organic carbon stock by improving soil quality, reducing erosion and soil disturbance. Fertilization has also been shown to have a positive influence on soil organic matter. Janzen (1987a) report that for a

continuous wheat rotation in the dark brown soil zone application of 45 kg N/ha/y for 24 years increased the organic carbon in the soil by 3.4 t/ha. Campbell and Zentner (1993) state another key to increasing soil organic matter is to increase plant biomass production and crop residue input into the soil. Carter (1992) reports that reduced tillage increased organic carbon in a fine sandy loam by 10 to 17 percent relative to conventional tillage during a three to five year period. Unger (1991) reports that in dryer soils where the soil is generally tilled to a depth less than 10 cm the effects of reduced tillage on soil carbon is often less significant. The effects of different tillage systems on the amount of carbon sequestered in topsoil is a complex issue that is imperfectly understood, but there is some evidence to suggest that reducing tillage, at least in the Canadian context, can increase the amount of carbon in topsoil.

8. DISCUSSION

Although the use of reduced tillage increased substantially in eastern Canada between 1991 and 1996, reducing the proportion of cropland area under conventional tillage from about 80 percent to about 65 percent in eastern Canada and from 67 percent to 51 percent in western Canada, indications are that the adoption of reduced tillage is levelling off in eastern Canada. This is not expected in western Canada. Direct energy use in the form of fuel declines under reduced tillage but indirect use embodied in chemical inputs, especially pesticides, generally increases. From an energy accounting perspective it is the net difference in these offsetting effects that matters. Furthermore, the available evidence suggests that energy productivity has improved dramatically in conventional tillage systems in the last 25 years. Given the production risks that have been identified in reduced tillage systems, improvements in management and technology in conventional tillage may be a more effective means of reducing energy use in agriculture in the future. In western Canada, zero tillage production systems offer more efficient use of energy in the form of fuel but this must be balanced against increases in the use of energy in the form of herbicides. Despite the large body of research showing the benefits of adopting zero tillage in western Canada, there are some areas which required continued research in order to further improve the economic performance of zero tillage. Zentner et al. (1998a) identify these main areas to include: a) develop improved methods of soil water conservation and stubble management in order to further enhance crop yields on a consistent basis, b) determine the suitability of present

nitrogen fertilizer recommendations since they were developed for use in conservation tillage systems, c) develop more efficient herbicide programs and application methods in order to deal with weeds and to allow for lower application rates, d) determine the suitability of new crops types which can be included in cereal rotations in order to extend and diversify the rotations, and e) determine the long-term impacts of conservation tillage methods on soil quality and the environment. In general, more empirical research is needed to better understand the overall effects of tillage systems on energy use in crop production and to further investigate the economic performance of reduced tillage production systems in light of recent innovations in technology and management. Many of the published comparative studies of profitability of alternative tillage systems are based on yield and cost data that are a decade old. Tillage system development has been one of the most dynamic areas of Canadian agriculture over the last ten years and comparisons of profitability based on outdated data are less than helpful for producers.

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